AN ECONOMIC MODEL FOR EVALUATING FACTORS AFFECTING BIOMASS REDUCTION AND FOREST RESTORATION

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ABSTRACT - Fire suppression and previous logging practices in many of the interior forested areas of the Pacific Northwest have set the stage for catastrophic wildfire, epidemic insect attack, and disease. Forest managers recognize that restoring these forests may require large-scale reduction of biomass. Although the tools currently used —prescribed fire, mechanical modification or reduction, and timber harvesting through thinning and biomass removal—are well established, forest managers lack comparative knowledge of their broad economic feasibility under varying market conditions. We present information on the financial practicality of forest restoration/biomass reduction, as well as a proposed framework for developing an economic model to better direct future planning and management of these stands and forests. Using this framework, we reviewed past and present mechanized timber harvesting and biomass removal case studies that were conducted in the Blue Mountain region of Oregon. Our sensitivity analysis examined variables such as percent pulpwood versus saw logs, harvesting methods and costs, and biomass quantities and removal. In this way, prescribed fire or biomass modification could then be compared with timber harvesting/removal to determine an economic break-even point.

INTRODUCTION

In the interior of the Pacific Northwest, dry conifer forests are at risk for catastrophic wildfire, epidemic insect attack, and disease. Eighty years of fire suppression and the selective harvest of ponderosa pine *(Pinus ponderosa)* have created record levels of biomass and conditions conducive to disaster (McIver et al. 1997). While forest managers recognize the need for biomass reduction and forest restoration, little is know about the economic trade-offs for alternative methods that reduce biomass. Information also is needed about the environmental impacts and operational feasibility for conducting these methods on the landscape level.

The four categories for biomass-reducing methods are:

- Prescribed Fire (planned ignition)
- Biomass removal (mechanical)
- Biomass modification (manual or mechanical)
- Leave alone

An economic model involving the first three methods is being constructed. This will be used to determine the economic feasibility of a given biomass-reduction treatment. By incorporating stand-specific attributes that affect production, costs, and revenues, the different treatments can be compared on the stand level and, ultimately, on the landscape level. A tool of this nature will provide insight for meeting management objectives for the reduction of biomass.

BIOMASS-REDUCTION METHODS

We define prescribed fire as a planned ignition by either manual or mechanical means. Typically a hand drip torch is used, but, when large-scale ignition is desired or conditions will allow, an aerial application (e.g., helitorch or plastic-sphere dispenser) might be a lower-cost alternative (Windell and Bradshaw 2000). The purpose is to consume all desired biomass (located primarily on the forest floor) and eliminate or kill the smaller suppressed trees while maintaining adequate live crowns in the co-dominant and dominant trees. After treatment, the stand can be put into a more historically based burn cycle.

Biomass *removal* is the harvesting and withdrawal of woody material that has merchantable value. For smaller wood, the most widely used method is a ground-based harvest system (i.e., mechanized cut-to-length). Although an aerial operation may be utilized, cost and availability of equipment can limit its application. Biomass *modification*, in contrast, is alteration of the fuel profile or minimization of any material that realizes no merchantable value (whether marketable or not). Although materials may be modified manually, the typical means is mechanical. Machines that crush, chop, and scatter the downed and standing material are ground-based and, therefore, limited by slope.

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STRUCTURE OF MODEL

The economic model we are developing consists of four modules. Each contains sublevels or calculators for information and parameters specific to the equipment or method used (Figure 1). These module-specific sublevels provide the data needed to determine treatment cost. The four modules are:

- Stand structure
- Prescribed fire
- Biomass removal
- Biomass modification

The sublevel calculators are:

- Production
- Cost
- Market

The stand structure module includes such attributes as number of trees per unit area, diameter distribution, biomass loading, biomass removal, and slope, which are some of the parameters that define particular operational conditions.

The prescribed fire module comprises both production and cost calculators. An estimated production rate per unit area or biomass per unit time can be derived, based on stand structure information and predicted fire behavior. The cost calculator uses required equipment, personnel, support crews, and planning information to determine operating cost per unit time. These details are then translated into a cost per unit area or biomass. In any calculator, a user-specified cost or value also could be entered.

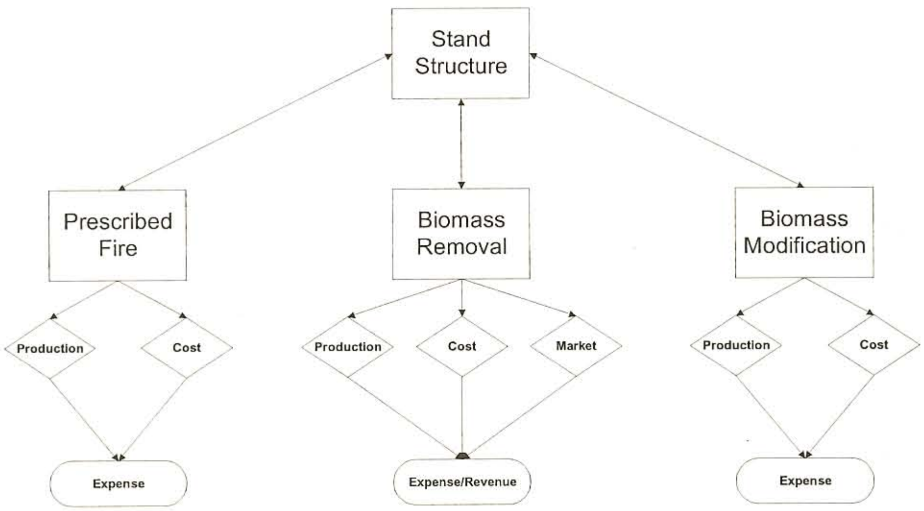

Figure 1. Framework for economic model.

The biomass removal module uses all three calculators. Based on data from a range of previous and present studies, production rates are predicted for different harvesting systems under the varying stand conditions. These are derived primarily from diameter distribution, biomass type (standing live, standing dead, and down material), and topography. The cost calculator, again, is based on equipment, personnel, support crews, and planning requirements. The market calculator contains information specific to the products being removed and their destination. Either a stump-to-truck or stump-to-mill cost can be determined. Current or predicted market prices by species and grade are factored, as well as the associated transportation cost to their respective destinations. These values are coupled with the stand structure information to determine revenues and hauling costs for the different sorts.

The biomass modification module is similar to the removal module, except that the market calculator is omitted.

AN EXAMPLE

We present a basic economic simulation for biomass removal via a mechanized, cut-to-length harvest system. Portions of this simulation have been simplified to minimize input and output size. For example, a mean diameter at breast height (DBH) was used to predict production rates. Typically, a diameter distribution would be included, and production values would vary based on the numbers of trees in their respective diameter classes. A recent study served as a check for the predicted values, directing a sensitivity analysis that utilized this basic model.

The simulated stand was dominated by ponderosa pine, with a mean DBH of 10 in. (25.4 cm), slopes ranging from –5 to 10%, and a total biomass removal of 30 tons per ac (66.2 metric tons per ha) (Table 1). Production and costs were derived from studies by Kellogg and Bettinger (1994), Brown (1995), Kellogg and Brown (1995), Doyal (1997), McIver et al. (1997), Drews et al. (1998), Hartsough (1998), Kellogg et al. (1998), Dodson-Coulter (1999), and Matzka and Kellogg (1999). Log and pulp prices were obtained from the current regional averages reported by the Oregon Department of Forestry (ODF 2000).

Output data were simulated for three types of single-grip harvesters: 1) a Rottne SMV purpose-build (P-Built) rubber-tired harvester; 2) a John Deere 653E purpose-built track-mounted harvester (Track); and 3) a retrofitted, tracked excavator with a Keto 500 dangle head (Retro). In all cases, the same, medium-sized 12-ton (10.7-metric ton) forwarder was paired with the harvesters. These machine combinations were compared against the percent saw logs removed, using a sensitivity analysis. Table 2 shows the total revenues.

Table 1. Inputs for basic economic model.

STAND

Mean DBH	10	inches
Slope range	-5 to +10	%
Removal	30	tons/acre

PRODUCTION and COST

Harvester	tons/PMH	$/hour	utilization
P-Built	35	135	70%
Track	25	125	70%
Retro	20	110	70%

Forwarder	tons/PMH	$/hour	utilization
Standard	15	110	85%

Layout and planning	75	$/acre
Support and misc.	20	%
P & Risk	15	%

MARKET

Log price	54	$/ton
Pulp price	31	$/ton
Hauling	10	$/ton

Table 2. Net revenues according to percent saw-log composition for three harvester types.

	Mechanized System Type (US $/acre)					
% saw logs	P-Built		Track		Retro	
100%	$	672	$	606	$	577
90%	$	603	$	537	$	508
80%	$	534	$	468	$	439
70%	$	465	$	399	$	370
60%	$	396	$	330	$	301
50%	$	327	$	261	$	232
40%	$	258	$	192	$	163
30%	$	189	$	123	$	94
20%	$	120	$	54	$	25
10%	$	51	$	(15)	$	(44)
0%	$	(18)	$	(84)	$	(113)

This output provided information on how revenues change with respect to saw logs quantities and the type of equipment used. In biomass-reduction studies by Doyal (1997) and Drews et al. (1998), the percent saw logs removed were 12% and 6%, respectively. Drews et al. (1998) showed that for a retrofitted harvester and a medium-sized forwarder, net revenues were positive, at $19.50/ton. Although this amount was considerably higher than in our simulation, one must consider that 50 to 60 tons per ac were removed during the previous study (almost double that in our example). To determine how tons-per-acre affected net revenues, we completed a sensitivity analysis with several simulation runs. When the retrofitted harvester system was assessed for percent saw logs by varying the tons-per-acre removed, net revenues both increased and decreased (Table 3). This was because, when more tons-per-acre were removed, the fixed costs per acre were distributed over the increased tonnage, thereby increasing net revenue. However, when pulp prices were too low, a cost for removal from the unit also was incurred.

Table 3. Net revenues for the retrofitted harvester, with respect to percent saw-log removal and tons-per-acre removed.

	Tons per Acre Removed			
%saw logs	30	40	50	60
100%	$ 577	$ 795	$ 1,012	$ 1,230
90%	$ 508	$ 703	$ 897	$ 1,092
80%	$ 439	$ 611	$ 782	$ 954
70%	$ 370	$ 519	$ 667	$ 816
60%	$ 301	$ 427	$ 552	$ 678
50%	$ 232	$ 335	$ 437	$ 540
40%	$ 163	$ 243	$ 322	$ 402
30%	$ 94	$ 151	$ 207	$ 264
20%	$ 25	$ 59	$ 92	$ 126
10%	$ (44)	$ (33)	$ (23)	$ (12)
0%	$ (113)	$ (125)	$ (138)	$ (150)

The market price for saw logs and pulpwood also differed significantly between the current example and the Drews' study. Because over 90% of the material removed was pulpwood, a sensitivity analysis considered only the variation in pulpwood prices. Table 4 demonstrates how a range of pulpwood prices (up to 50% over the current price) affect the net revenues with respect to percent saw-log removal (Prices at the time of the Drews' study were almost 90% higher). In our example, a pulpwood-price increase of 5 to 10% made the harvesting of all material profitable at a removal level of 60 tons per ac.

To test the model further, we added the actual values for pulpwood and saw logs, transportation, layout, and profit and risk, as found in the Drews' study. These results are shown in Table 4. The predicted value from the model for the 6% saw-log and 94% pulpwood mix was within 5% of the value reported by Drews et al. (1998).

Table 4. Net revenues for the Retro machine at 60 tons per ac, with respect to percent saw-log removal and percent change in pulp price.

	Percent Change in Pulp Prices				
%saw logs	0%	5%	10%	50%	Drews
100%	$ 1,230	$ 1,230	$ 1,229.7	$ 1,230	$ 2,559
90%	$ 1,092	$ 1,101	$ 1,110.3	$ 1,185	$ 2,397
80%	$ 954	$ 972	$ 990.9	$ 1,140	$ 2,235
70%	$ 816	$ 844	$ 871.5	$ 1,095	$ 2,073
60%	$ 678	$ 715	$ 752.1	$ 1,050	$ 1,911
50%	$ 540	$ 586	$ 632.7	$ 1,005	$ 1,749
40%	$ 402	$ 458	$ 513.3	$ 960	$ 1,587
30%	$ 264	$ 329	$ 393.9	$ 915	$ 1,425
20%	$ 126	$ 200	$ 274.5	$ 870	$ 1,263
10%	$ (12)	$ 71	$ 155.1	$ 825	$ 1,101
0%	$ (150)	$ (57)	$ 35.7	$ 780	$ 939

SUMMARY

The structure of our economic model will allow forest managers to compare different biomass-reduction alternatives under various stand, operational, and market conditions. A basic example illustrated possible outputs. With this tool, different attributes can be varied to determine the break-even conditions that make an operation profitable or more economically feasible. In cases where no merchantable material is removed (e.g., prescribed fire or biomass modification) a direct cost will result. However, many options and combinations of methods and treatments could be investigated that might have a lower cost. Furthermore, modifying the silvicultural prescription may result in quantities of merchantable material that could lower cost or make a treatment profitable.

Stand restoration is becoming more complex at both the stand level and across the landscape. For biomass reduction to work on the scale currently needed, sound economic decisions that explore the many options available are required. The model presented here will provide insight and better direct future management decisions.

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